ALASKA OREGON WASHINGTON

PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-209 November 1973

LATEST RESULTS FROM THE PRINGLE FALLS PONDEROSA PINE SPACING STUDY

by

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ABSTRACT

Logging old-growth ponderosa pine carefully, thinning the understory saplings, and controlling the brushy understory vegetation appear to have distinct growth advantages over clearcutting and planting. Possibly 10 years of stand growth may be saved by treating the brushy understory vegetation in the early part of the rotation. Additional years will be saved by using the existing understory trees instead of planting. Saplings thinned 8 years earlier to 125 trees per acre grew three times the cubic wood volume that was being produced by the old-growth overstory before harvest. Periodic increment of the sapling stand is rising rapidly and may soon produce five to six times that of the overstory.

Keywords: Thinning (trees), ponderosa pine, forest improvement cutting, stand density.

Precommercial thinning prescriptions in ponderosa pine stands following overstory removal offer foresters a remedy when the overstory is producing minimal wood and the understory saplings and small poles are too dense to produce a merchantable log in a reasonable length of time. Results from recent spacing studies[1/][2/] have led some managers to space trees farther apart.

Varying product and land use objectives have contributed to the diversity in tree densities imposed upon the stands in the Northwest. Densities of thinned stands range from 500 to 120 trees per acre. Sites range from heavily grazed pine grass (*Calamagrostis rubescens*) to plant communities having waist high manzanita (*Arctostaphylos parryana* var. *pinetorum*) and snow-brush (*Ceanothus velutinus*). Thinning, spacing, and slash treatment have had an influence on understory vegetation development; and this vegetation in turn has had a competitive effect on tree growth in certain plant communities.

Selection of an initial spacing for a particular stand dictates, to a large degree, the management regime for the rotation. Therefore, this selection must be made carefully with due consideration for products to be produced, the machinery to harvest them, and future markets. Ideally, a spacing should be selected that will promote reasonably free growth until the time when the desired merchantable product can be harvested. If too narrow a spacing is chosen, growth may slow to unacceptable levels before we have a merchantable product. If this happens, the manager is faced with the necessity of making another investment in thinning without a salable product and, in addition, he has lost forever the wood that could have accumulated on usable trees had a lesser density been chosen. In essence, the purpose of spacing studies is to determine that point in time and product size when growth begins to slow because of competition between trees at a particular spacing. Ultimately we want to know the spacing or level of stocking at different points in time that will give us maximum mean annual increment in volume for a given product or product mix.

Forest managers who wish to evaluate past thinning in sapling stands or those contemplating future thinning will find this paper useful. Twelve-year

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[1/] James W. Barrett. Ponderosa pine saplings respond to control of spacing and understory vegetation. USDA For. Serv. Res. Pap. PNW-106, 16 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg. 1970.

[2/] James W. Barrett. Response of ponderosa pine pole stands to thinning. USDA For. Serv. Res. Note PNW-77, 11 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg. 1968.

growth results are presented here from a spacing study designed to give the manager a wide range of alternatives from which to choose an initial spacing.

The reader is encouraged to use this note in conjunction with results published in 1970 (see footnote 1) which contain a detailed description of the study design and 8-year growth results.

STAND BEFORE TREATMENT AND THE STUDY AREA

Before study installation, the timber stand consisted of old-growth ponderosa pine with unthinned 40- to 70-year-old sapling understory averaging 1 inch in diameter and 8.2 feet in height (fig. 1). There were about 20 overstory trees per acre that averaged 850 board feet per tree. Shrubs under dense understory trees were small suppressed plants but well developed where the sapling understory was sparse or nonexistent.

Soil is a regosol developed in dacite pumice originating from the eruption of Mount Mazama (Crater Lake) 7,300 years ago. Old-growth ponderosa pine in the area indicates a height of 78 feet at age 100, average site quality.[3] Experimental plots are in a transition zone between *Pinus ponderosa/Purshia tridentata-Arctostaphylos patula* and *Pinus ponderosa/Ceanothus velutinus-Purshia tridentata* plant communities.[4] The study area is located on the Pringle Falls Experimental Forest, 35 miles southwest of Bend in central Oregon.

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EXPERIMENTAL DESIGN AND METHODS

Study design consists of 30 rectangular 0.192-acre plots thinned to spacings of 6.6, 9.3, 13.2, 18.7, and 26.4 feet. A one-half-chain-wide buffer area around each plot was thinned to the same density as the inner plot. Each spacing was replicated six times. Understory vegetation was removed on three of the six replications for each treatment. Tree and vegetation measurements were made every 4 years for 12 years. Percent cover of understory vegetation on 15 plots was measured by systematic sampling of 100 points per

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[3] Walter H. Meyer. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agric. Tech. Bull. 630 (rev.) 59 p., illus. 1961.

[4] Jerry F. Franklin and C. T. Dyrness. Vegetation of Oregon and Washington. USDA For. Serv. Res. Pap. PNW-80, 216 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg. 1969.

Figure 1.--*Timber stand before logging and thinning saplings (top); 12 years later after thinning saplings to 250 per acre and controlling understory vegetation (bottom left) and allowing understory to develop (bottom right).*

plot.[5] An estimate of average crown width was made by measuring crown diameter on 12 sample trees per plot and then regressing crown width on stem diameter.

RESULTS

Diameter Growth

Widely spaced trees grew significantly better than closely spaced trees during the third period (fig. 2). Growth rate has changed little from the second period to the third although there appears to be a trend of diminishing rates with time at the two narrowest spacings.[6] This may be the first hint of increasing competition between trees. Trees with the two widest spacings continue to grow at a rate of from 3.4 to 5.6 inches per decade.

Understory vegetation, 8 to 12 years after thinning, is still causing substantial reductions in growth at the widest spacings. For example, diameter growth at the widest spacing was reduced 30 percent by understory vegetation, and trees at the 18.7-foot spacing grew 15 percent less where there was understory vegetation. Understory vegetation continues to be most competitive at wider spacings and less at narrow spacings. However, the magnitude of this interaction seems to be diminishing. Relative to the second period, the effect of vegetation appears to be increasing at closer spacing and decreasing at wider spacings. However, there are inconsistencies in these trends which suggest changes are taking place in the interrelationships of tree growth and understory vegetation development that cannot be accurately assessed at present.

The largest diameter trees in each spacing continue to grow fastest (fig. 2). Although these trees appear to dominate the site in a localized area around the tree, competition from other trees does reduce their growth. To illustrate this, figure 2 shows that where 62 trees were left and the brush removed, these trees grew at an average rate of 0.56 inch per year. But where the 62 largest trees were selected from a stand containing 125, 250, 500, and 1,000 trees, growth (indicated by the solid line in figure 2) lessened as stand density increased. The same relationships were true where competitive understory vegetation was left.

At the end of the last measurement period, average diameter (table 1) ranged from 3.7 inches at the narrowest spacing to 8.4 inches where vegetation was removed. Some individual trees at the widest spacing have already attained a diameter of over 10 inches.

5/ Harold F. Heady, Robert P. Gibbens, and Robert W. Powell. A comparison of the charting, line intercept, and line point method of sampling shrub types of vegetation. J. Range Manage. 12: 180-188, illus. 1959.

6/ Spacing x periods interaction was highly significant. Of the plots at the two closest spacings, 83 percent show declining rates from the first period.

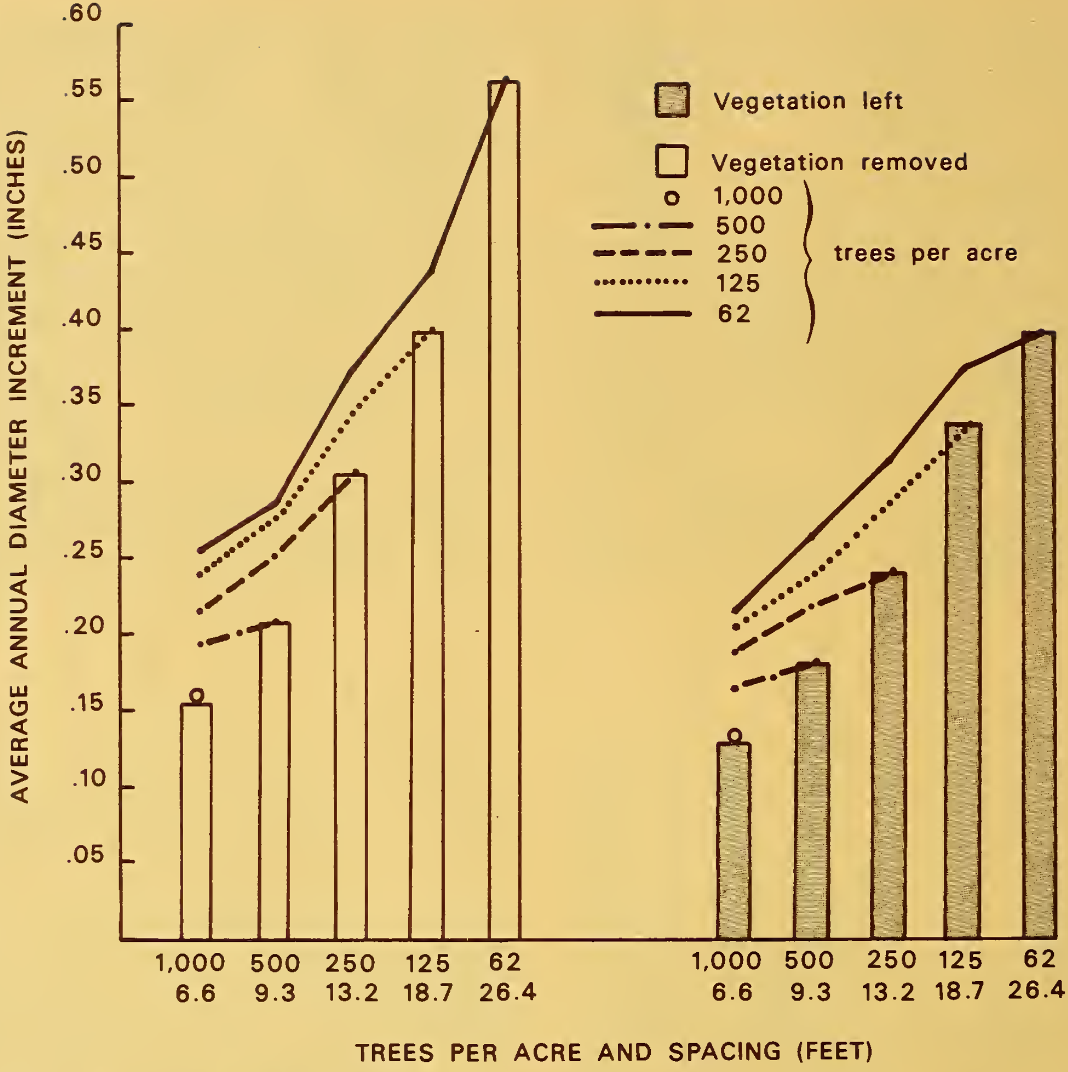

Figure 2.--*Average annual diameter (during third period) increment of ponderosa pine saplings thinned to various spacings (arithmetic average increments based on trees that lived through the period). Bars show diameter growth for total number of trees at each spacing. Points above bars show growth of the stated number of the largest well-distributed trees within the stand.*

Table 1.--*Average diameter*[1/] *of ponderosa pine saplings in 1959, 1963, 1967, and 1971*

Treatment and year	Trees per acre and spacing (feet)				
	1,000 (6.6)	500 (9.3)	250 (13.2)	125 (18.7)	62 (26.4)
	Inches				
Vegetation left:					
1959	2.0	1.9	2.1	2.2	2.2
1963	2.6	2.6	3.0	3.4	3.4
1967	3.2	3.4	4.0	4.7	4.7
1971	3.7	4.1	4.9	6.0	6.3
Vegetation removed:					
1959	1.7	1.8	1.9	2.5	2.2
1963	2.4	2.8	3.3	4.1	3.8
1967	3.1	3.7	4.6	5.7	6.2
1971	3.7	4.5	5.8	7.3	8.4

1/ Quadratic mean.

Basal Area

Maximum basal area (74 square feet) at the end of 12 years occurred where 1,000 trees per acre were left (table 2). In contrast, the stand containing 62 trees per acre had only 13.6 square feet where understory vegetation was left and 24 square feet where it was removed.

Periodic basal area growth continues to increase at all spacings, with the highest increment 5.7 square feet per acre per year at the narrow spacing where vegetation was removed. Basal area is still increasing most rapidly per unit of basal area at the wider spacings. At the widest spacing where vegetation was removed, basal area increment averaged 3.7 square feet per acre per year during the last period. This increment on only 62 trees suggests that these widely spaced, fast growing trees can rapidly accumulate a growing stock base capable of reasonable wood production per acre.

Eight years after thinning, no real confidence can yet be placed in basal area as an aid to predicting diameter increment (table 2). When periodic annual diameter increment is regressed on basal area at the beginning

Table 2.--*Average basal area per acre of ponderosa pine saplings directly after thinning and 4, 8, and 12 years later*[1/]

Treatment and year	Trees per acre				
	1,000	500	250	125	62
			Square feet		
Vegetation left:					
1959	22.4	9.8	5.8	3.4	1.6
1963	37.1	18.4	12.4	7.8	3.8
1967	54.0	32.0	21.3	14.9	7.7
1971	73.7	46.6	32.8	24.7	13.6
Vegetation removed:					
1959	16.6	8.4	4.9	4.1	1.7
1963	32.0	20.8	14.5	11.4	5.0
1967	51.2	37.2	28.6	22.4	12.9
1971	74.1	55.7	45.3	36.7	24.1

[1/] Differences between values reported here and in USDA Forest Service Research Paper PNW-106 (James W. Barrett, Ponderosa pine saplings respond to control of spacing and understory vegetation, Pac. Northwest For. & Range Exp. Stn., Portland, Oreg., 1970) are due to averaging and rounding errors.

of the period, three different regression lines are evident, one for each period (fig. 3). As diameters approach merchantable sizes, periodic regressions may be similar and basal area could become useful separately or in combination with other variables as a predictor of increment.

Height Growth

A marked increase in periodic height growth took place from the first to the third period with threefold increases at the widest spacings (fig. 4 and table 3). With one exception, increase in growth rate between periods 2 and 3 exceeded that between 1 and 2.

Not all individual trees responded at the same time. Increased growth after thinning was visually detected in the first period at the widest spacing

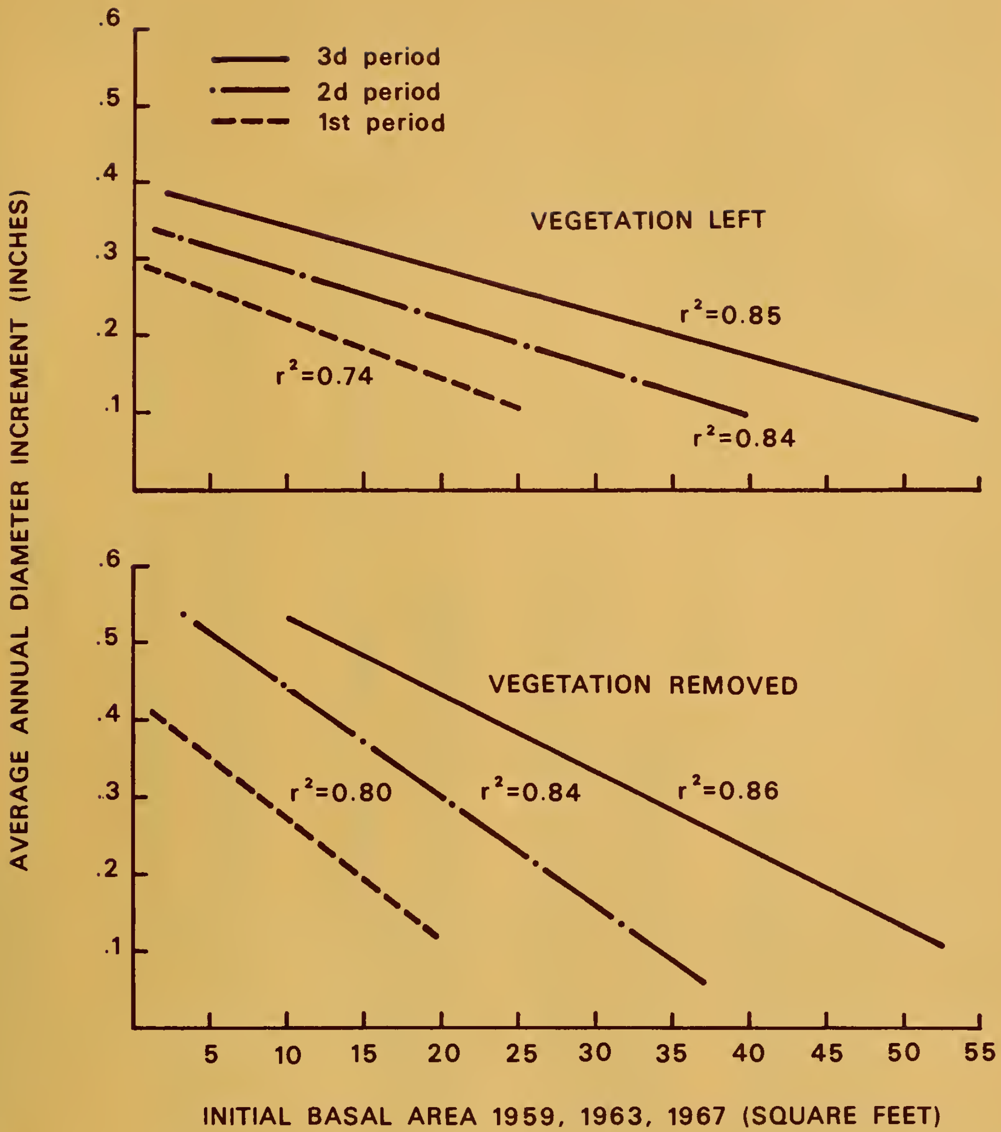

Figure 3.--*Relation of diameter increment to basal area at the beginning of each growth period.*

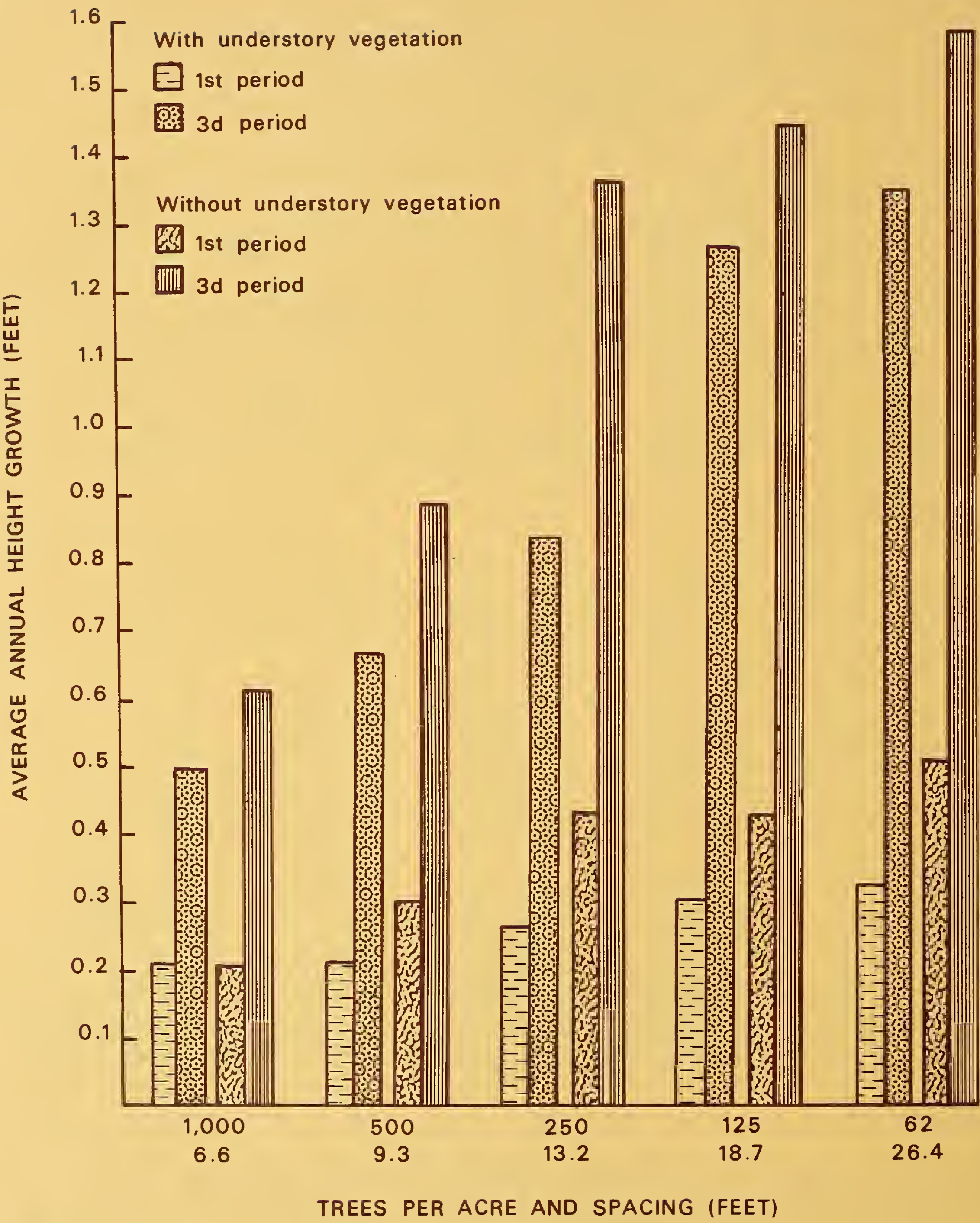

Figure 4.--*Average annual height growth during the first and third 4-year growth periods.*

Table 3.--*Average*[1/] *height of ponderosa pine saplings in 1959, 1963, 1967, and 1971*

Treatment and year	Trees per acre and spacing (feet)				
	1,000 (6.6)	500 (9.3)	250 (13.2)	125 (18.7)	62 (26.4)
			~~Inches~~ Feet		
Vegetation left:					
1959	12.6	11.1	11.5	12.3	11.5
1963	13.4	12.0	12.5	13.5	12.9
1967	14.5	13.3	14.3	15.9	15.6
1971	16.5	15.9	17.6	21.0	21.0
Vegetation removed:					
1959	10.6	10.2	10.3	14.2	11.9
1963	11.4	11.5	12.0	15.9	13.9
1967	12.6	13.4	15.3	19.3	18.7
1971	15.1	17.0	20.7	25.1	25.0

1/ Average of trees living through the period.

on a few trees. As time passed, variation from tree to tree lessened and trees at the wide spacing grew uniformly well. After 12 years, this erratic height response can still be seen at the 6.6- and 9.3-foot spacings with some good trees at the 6.6 spacing making very little height growth and other similar trees making notable height growth.

In the third period, understory vegetation continued to significantly reduce height growth on all spacings although there appears to be some tendency for this effect to diminish in the third period. The trend for understory vegetation to have a greater effect on height growth at the wider spacings during the first and second periods did not continue in the third period, indicating that understory vegetation probably had a uniform effect over the range of spacings.

Cubic Volume Increment

In the third period, volume growth continued to be better where understory vegetation was removed in all but the closest spacing (fig. 5). Also, the trend for understory vegetation to have a greater effect at wider spacings remained.

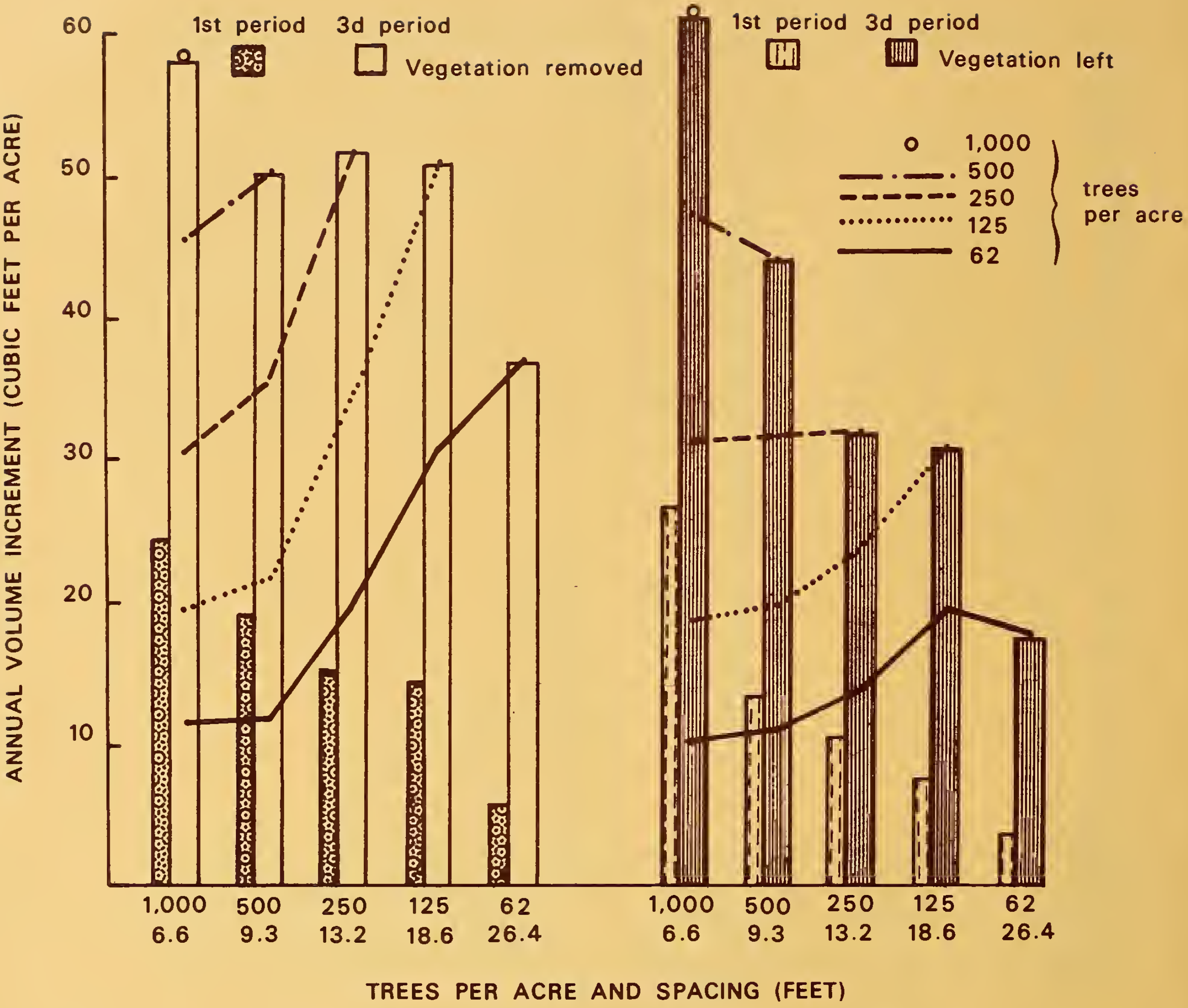

Figure 5.--*Periodic annual volume increment of ponderosa pine saplings thinned to various spacings. Bars show increment for total number of trees at each spacing. Points within bars show increment of the stated number of the largest well-distributed trees within the stand. (First period increments based on pooled equation. See footnote 1 table 4).*

Growth of the largest diameter trees tends to increase with wider spacings. For example, in figure 5 where vegetation was removed, the 125 largest diameters in the 500-tree-per-acre stand produced 21 cubic feet; but where only 125 trees were left, over twice that was produced.

As one might expect, the greatest amount of wood was produced at the highest density where we find many small spindly stems that may never reach merchantability. However, growth per acre may be improving more rapidly at wider spacings than at narrow ones. For example, it is encouraging to note that spacings of 9.3, 13.2, and 18.6 where vegetation was removed produced about the same amount of volume. Although this seems somewhat unrealistic at this early stage in stand growth, it does point out the capacity of only 125 trees per acre to produce wood.

The stand with 1,000 trees per acre with understory vegetation removed contains an average of 602 cubic feet per acre 12 years after thinning (table 4). The 125-tree-per-acre stand where vegetation was removed contains about two-thirds this amount and consists of trees that will surely reach merchantability.

Mortality

Out of a total of 2,232 trees, 23 died in the 12 years following establishment of the study. The 6.6 spacing lost 1.2 percent during this time. The 9.3 and 13.2 spacings lost 0.6 and 2.0 percent, respectively. No trees were lost in the two widest spacings.

Crown Characteristics

Tree crowns at the wider spacing were longer and wider 12 years after thinning and thus contained more spatial volume than crowns of trees at the narrower spacings. As might be expected, crown growth responded to additional growing space and control of vegetation much the same as diameter and height growth. For example, if we compare extremes, crowns of trees at the widest spacing where vegetation was removed contained seven times the volume of a crown of an average tree at the narrowest spacing where vegetation was left. In addition, crown size at the end of the third period was just as sensitive statistically to spacing and understory vegetation as diameter, height, and volume increment. This was also true when only the 62 largest trees per acre at each spacing are considered (fig. 6). Thus, crown development of even the best trees in the higher density stands is affected by density and understory vegetation.

Table 4.--*Net yield of ponderosa pine saplings at the end of the first, second, and third 4-year periods*

Treatment	Trees per acre				
	1,000	500	250	125	62
	----------------Cubic feet---------------- Per acre				
1st period:					
Vegetation left	185	77	45	25	11
Vegetation removed	133	66	35	32	13
2d period:[1/]					
Vegetation left	409	205	163	117	57
Vegetation removed	370	258	219	200	108
3d period:					
Vegetation left	654	381	291	241	127
Vegetation removed	602	459	426	403	255

[1/] Linear equations expressing volume as a function of height and diameter (diameter squared x height) were used in all three periods. First two period increments as reported in USDA Forest Service Research Paper PNW-106 (James W. Barrett, Ponderosa pine saplings respond to control of spacing and understory vegetation, Pac. Northwest For. & Range Exp. Stn., Portland, Oreg., 1970) were based on pooled measurements from 186 trees. Additional trees on each plot were measured in 1967 making a total of 12 per plot. During the last period, volumes were estimated using a separate equation for each plot. Thus, the difference between second period volumes reported here and in USDA Forest Service Research Paper PNW-106 is accounted for.

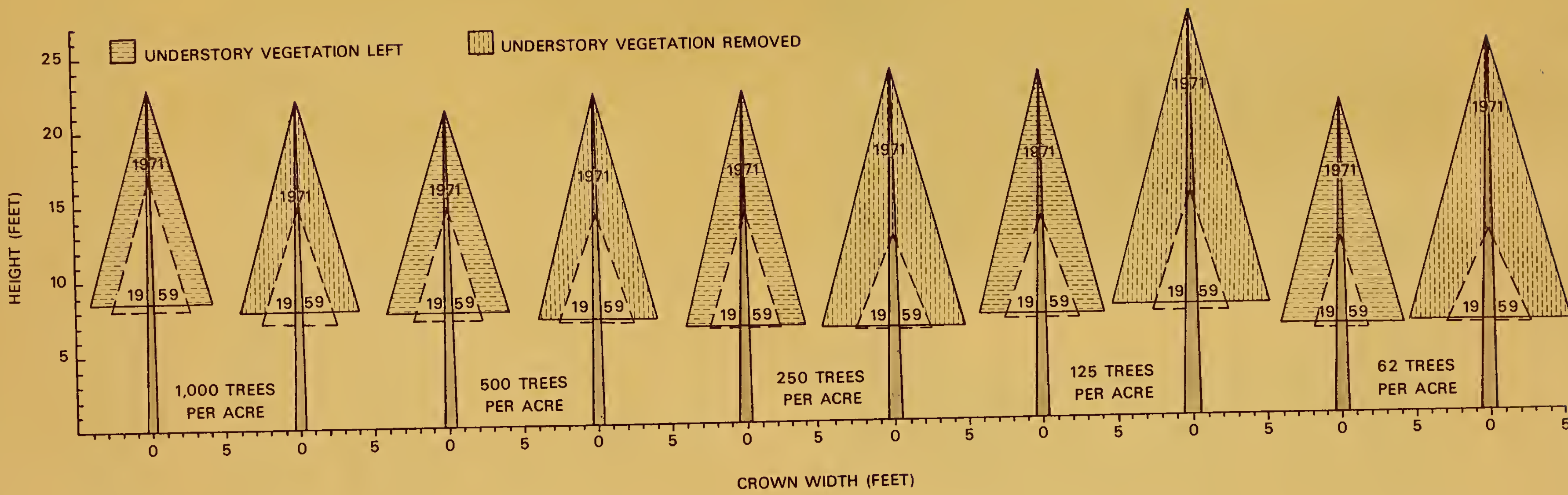

Figure 6.--Average crown dimensions of the 62 largest diameter trees per acre in 1959 and 12 growing seasons later. Crown widths for 1959 were estimated from 1971 regressions of crown width on diameter.

Crown cover probably has a notable influence on the development of understory vegetation. When we consider crown cover in terms of average crown diameter per treatment, it is evident why understory vegetation has not developed to as great an extent as where 1,000 trees per acre were left. Percent of ground covered by crown at the end of the last period is:

Number of trees per acre and spacing (feet)	Understory vegetation left	Understory vegetation removed
	(Percent of ground covered)	
1,000 (6.6)	64	73
500 (9.3)	39	44
250 (13.2)	22	35
125 (18.7)	16	23
62 (26.6)	8	13

Where understory was left, eight times as much ground is canopied by the stand containing 1,000 trees per acre as where 62 trees per acre were left. However, individual crowns on the widest spacing are visibly dense and probably offer more cover per tree than those at the narrowest spacing.

Understory Vegetation

Changes in understory vegetation development from 1967 to 1971 were minor. Essentially the same trends continued. Ground covered by brush was greater at the wider spacings (fig. 7) with 48 percent of the ground covered at the widest spacing and 35 percent at the narrowest spacing. Changes in proportional distribution of species were minor with bitterbrush (*Purshia tridentata*), the principal species occupying 17 to 22 percent of the area 12 years after thinning (fig. 8).

Where understory vegetation was allowed to develop naturally, suppressed ponderosa pine seedlings have also responded to the additional growing space. As shown in figure 9, some seedlings, barely visible below the brush at time of thinning, 12 years after thinning are breast high or higher. These trees will probably offer notable competition to the crop trees within a short time. Herbicide application just after thinning may not eliminate this source of competition, although some seedlings could be destroyed in a first commercial thinning.

Figure 7.--*Ponderosa pine saplings thinned to a wide spacing 12 years earlier. Understory vegetation controlled (left) and allowed to develop naturally (right).*

APPLICATION AND DISCUSSION

This note is a progress report of a study that is gradually providing us with growth information necessary to make timber management decisions. For example, latest diameter and height growth rates may be roughly projected a decade or two to forecast about when a product may be harvestable under a certain initial spacing. Basal area appears to be a poor predictor of diameter increment at this early age and size, and such methods seem risky until trees are larger.

Mature overstory close to this study is growing about 100 board feet per acre per year (between 15 and 20 cubic feet).[7] Understory saplings

[7] Edwin L. Mowat. Growth after partial cutting of ponderosa pine on permanent sample plots in eastern Oregon. USDA For. Serv. Pac. Northwest For. & Range Exp. Stn. Res. Pap. 44, 23 p., illus., Portland, Oreg. 1961.

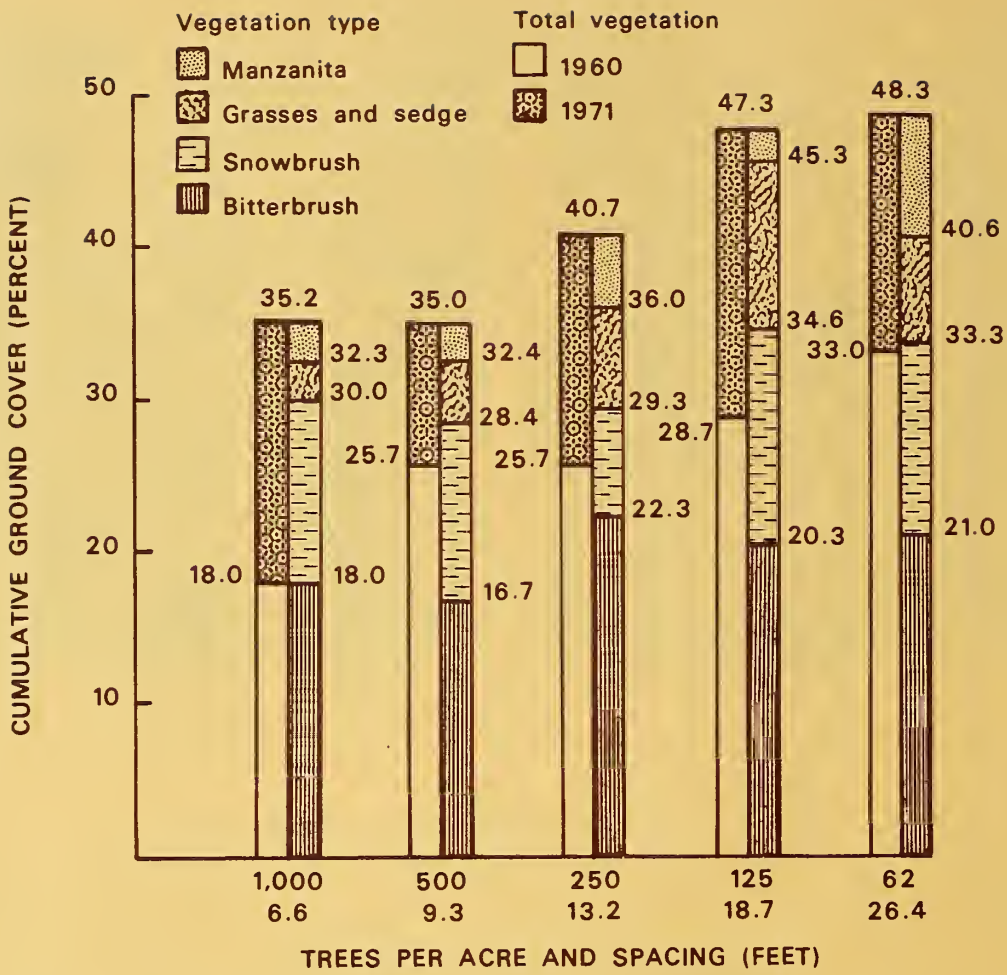

Figure 8.--*Average percent of ground covered by understory vegetation in 1960 and 1971 and percent covered by type of vegetation in 1971. Two growing seasons elapsed between overstory removal and actual measurement of the vegetation in 1960. Thus, enough time probably passed to establish differences between spacing before vegetation cover estimates were made initially.*

Figure 9.--*Plot thinned to a wide spacing, showing development of brushy understory vegetation and young seedling trees that have also taken advantage of additional growing space.*

thinned to 125 trees per acre are, after only 8 years, producing almost three times the cubic wood increment of the old-growth overstory stand. Also, the sapling stand is at the stage where periodic increment is rising rapidly and will soon be producing five to six times that of the overstory (an encouraging outlook for converting old-growth pine stands to second growth).

Forest managers confronted with the obstacles of harvesting overstory and saving the sapling-size understory trees often succumb to the "easy way out" of clearing the land and planting. This "way" will destroy increment that may never be recovered. Although figure 10 is not a direct comparison, it does show the results of planting and not controlling understory vegetation versus saving the existing reproduction and controlling understory vegetation. Trees on the right average 23.8 feet in height and 7 inches in diameter, and those on the left average 9.1 feet high and 1.9 inches in diameter. The planted stand averages slightly less than trees on the right directly after thinning 12 years earlier.

Contradicts

Results here suggest that possibly a decade[8] of tree growth might be

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[8] Average diameter growth of 125 trees per acre with brush and without brush was projected to a point where both stands contained 125 square feet of basal area (the density assumed to check understory vegetation). The stand where vegetation was controlled "attained" 125 square feet 10 years before the stand where vegetation was allowed to develop naturally.

Figure 10.--*Small pole stand on right was a suppressed sapling stand in this study 12 years earlier. Saplings were thinned to 125 trees per acre and vegetation controlled. Plantation on left was established in a log landing 1 year after thinning stand on right and controlling understory vegetation.*

saved by treating the understory vegetation twice during the early part of the rotation. One might speculate on the possibility of treating the stand described here in the following order:

1. Overstory harvest.
2. Thinning 1 year after overstory removal.
3. Thinning slash disposal.
4. Spray understory vegetation when 15 percent or more of the ground is covered by understory vegetation.
5. Spray understory vegetation when ground cover again reaches 15 percent.
6. Spray no more but allow trees and vegetation to develop naturally.

The time interval between brush treatments will depend largely on the presence or absence of sprouting varieties of brush.[9]

It should be noted that some degree of discretion needs to be exercised in controlling understory vegetation. Benefits from brush have been recognized for some time.[10] Bitterbrush and snowbrush ceanothus are both nitrogen fixers and furnish forage and cover for wildlife. Also, they are probably an important link in the soil-plant-water continuum on pumice soils. On the other hand, there is ample evidence in the forests of central Oregon to indicate that some stands can maintain notable productivity for several decades without the presence of brush and without evidence of deterioration of the site. In other instances, stand density has kept brush development in check by crown closure, and trees and brush existed together in an acceptable forest community.

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[9] The long-time effects of keeping the land entirely free of understory vegetation are being studied in a cooperative effort between the Department of Soil Science, Oregon State University, Corvallis, and the Pacific Northwest Forest and Range Experiment Station.

[10] C. T. Youngberg. Silvicultural benefits from brush. Soc. Am. For. Proc. 1965: 55-59. 1966.

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